SHEET (1)

"BOUNDARY LAYER THEORY"

1. The velocity distribution in the boundary layer is given by $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$, δ being boundary layer thickness. Calculate the following:

   a) Displacement thickness,

   b) Momentum thickness, and

   c) Energy thickness.

2. If velocity distribution in laminar boundary layer over a flat plate is assumed to be given by second order polynomial $u = a + by + cy^2$, determine its form using the necessary boundary conditions.

3. The velocity distribution in the boundary layer is given by $\frac{u}{U} = \left(\frac{y}{\delta}\right)^{\frac{1}{7}}$ Calculate the following:

   a) Displacement thickness,

   b) Momentum thickness,

   c) Shape factor

   d) Energy thickness and,

   e) Energy loss due to boundary layer if at a particular section, the boundary layer thickness is 25 mm and the free stream velocity is 15 m/s. If the discharge through the boundary layer region is 6 m^3/s per meter width, express this energy loss in terms of meters of head. Take $\rho = 1.2$ kg/m^3.

4. In the boundary layer over the face of a high spillway, the velocity distribution was observed to have the following form:

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{0.22}$$

The free stream velocity U is 20 m/s and boundary layer thickness 5 cm at a certain section. The discharge is 5 m^3/s per meter length of spillway. Calculate displacement thickness, energy thickness and loss of energy up to section under consideration

5. In the boundary layer over the face of a high spillway, the velocity distribution was observed to have the following form:

$$\frac{u}{U}=\left(\frac{y}{\delta}\right)^{0.22}$$

The free stream velocity U at a certain section was observed to be 30 m/s and a boundary layer thickness of 60 mm was estimated from the velocity distribution measured at the section. The discharge passing over the spillway was 6 m^3/s per meter length of spillway. Calculate:

a) The displacement thickness,

$$\frac{u}{U}=\left(\frac{y}{\delta}\right)^{0,22}$$

b) The energy thickness, and

c) The loss of energy up to the section under consideration.

6. A smooth plate 2 m wide and 2.5 m long is towed in oil (sp. gr. 0.8) at a velocity of 1.5 m/s along its length. Find the thickness of boundary layer and shear stress at the trailing edge of the plate. $\nu_{oil}=10^{-4}\,m^2/s$.

7. A plate 450 mm x 150 mm has been placed longitudinally in a stream of crude oil (specific gravity 0.925 and kinematic viscosity of 0.9 stoke) which flows with velocity of 6 m/s. Calculate:

a) The friction drag on the plate.

b) Thickness of the boundary layer at the trailing edge, and

c) Shear stress at the trailing edge.

8. Air is flowing over a flat plate 5 m long and 2.5 m wide with a velocity of 4 m/s at 15°C. If ρ= 1.208 kg/m^3 and ν = 1.47 x 10^{-5} m^2/s, calculate:

a) Length of plate over which the boundary layer is laminar, and thickness of the boundary layer (laminar).

b) Shear stress at the location where boundary layer ceases to be laminar. and

c) Total drag force on both sides on that portion of plate where boundary layer is laminar.

9. Atmospheric air at 20°C is flowing parallel to a flat plate at a velocity of 2.8 m/s. Assuming cubic velocity profile and using exact Blasius solution estimate the boundary layer thickness and the local co efficient of drag (or skin friction) at x = 1.2 m from the leading edge of the plate, Also find the deviation of the approximate solution from the exact solution. Take the kinematic viscosity of air at 20°C=15.4 x 10^{-6} m^2/s.

10. Airflows over a plate 0.5 m long and 0.6 wide with a velocity of 4 m/s. The velocity profile is in the form $\frac{u}{U} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$ If ρ = 1.24 kg/m^3 and ν = 0.15 x 10^{-4} m^2/s. calculate: (i) Boundary layer thickness at the end of the plate, (ii) Shear stress at 250 mm from the leading edge. and (iii) Drag force on one side of the plate.

11. Find the ratio of friction drag on the front half and rear half of the flat plate kept at zero incidence in a stream of uniform velocity, if the boundary layer is laminar over the whole plate.

12. Air at standard conditions is flowing over a flat plate which is 1 m long and 0.3 m wide. The flow is uniform at the leading edge of the plate. The velocity profile in the boundary layer is assumed to $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$ as the free stream velocity is U = 30 m/s. Assume that the flow conditions are independent of Z Using control volume abcd. shown by dashed line. calculate the mass flow rate across the surface ab. [Density of air may be taken as 1.23 kg/m^3, refer to Fig. 1.1]

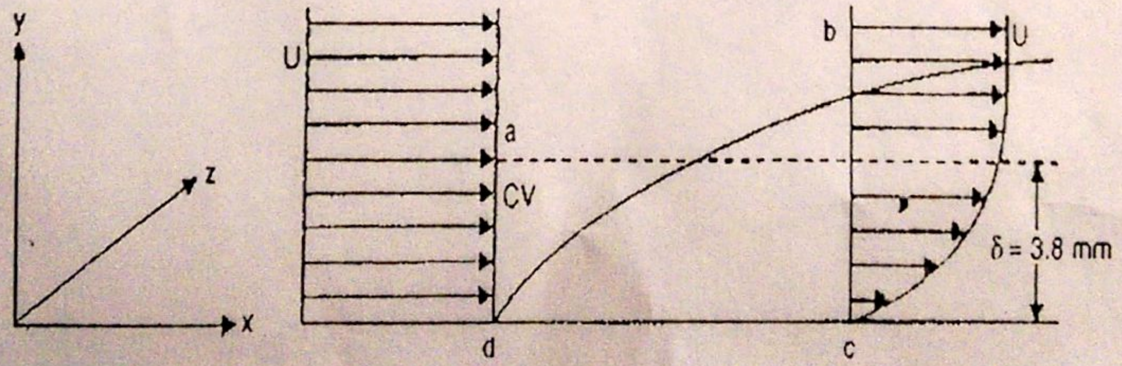

Fig. 1.1